On some examples of Cone-in-Cone Structure.

By Prof. GRENVILLE A. J. COLE, F.G.S.

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PROBABLY everyone who has considered the arrangement of the constituents of an aggregate composed of radially grouped fibres has realised that the individual fibres are conical or pyramidal in form, their apices meeting in the centre of the aggregate. In a coarse example of this mode of crystallisation, such as the calcite concretions in the magnesian limestone of Durham, this conical form of the constituent crystals is very easily seen; the cones cleave across, where composed of a cleavable mineral, showing that the particles composing them have the same orientation within the limits of the cone, and that each cone, in fact, is a crystal, bounded ultimately by contact with its neighbours. It should, therefore, be polygonal in cross section, if neighbouring cones have developed equally so as to meet it.

Such groupings of crystallites to form crystalline cones are familiar features of the growth of spherulites in igneous rocks. Often these spherulites are developed from a surface, so that they form only hemispheres, their bases against the originating surface. Where a number of points on a surface of cooling serve as starting-points for radial groups of crystalline fibres, conical structure, rather than true spherulitic growth, predominates, and the interstices between the cones, or bunches of fibres, become filled up by similar growths on a smaller scale. A zone of fibrous matter thus forms from the originating surface outwards, terminating in a mammillated exterior when conditions favourable to crystallisation no longer prevail.

Should, however, a second surface, say a crack in the consolidating rock, lie parallel or approximately parallel to the surface from which crystallisation has spread, the conical groups of fibres will terminate in their outward growth against this second surface, and flat-topped cones of crystallisation will take the place of hemispheres or mammillated aggregates. A beautiful illustration of this appears in Mr. Rutley's drawing of an obsidian from Pilas, Mexico.[1]

The connection between radial crystallisation and cone-in-cone structure, was, it is scarcely necessary to say, fully grasped by Dr. Sorby in 1859.[2] He compared cone-in-cone structure to oolitic grains in which fibrous crystallisation had taken place entirely on one side of the centre of aggregation, and wrote, "by the mutual interference of contiguous groups, and of others contained within themselves, there was formed a mass of irregular cones enclosing other cones." He concluded that "this structure is one of the peculiar forms of concretions, formed after the deposition of the rock in which they occur, by the crystallisation of the carbonate of lime and other isomorphous bases."

Mr. John Young,[3] in his last letter on this subject, seems still to attribute to faulty observation or to badly preserved specimens the cases where the apices of cones have been recorded as pointing in towards one another. But previously he has been careful to restrict his theory of the mechanical origin of cone-in-cone to the specimens that he had selected for description[4] in 1885,[5] so it may be taken for granted that another theory is required to account for such cases as Mr. Gresley has brought forward,[6] where concretions have cone-in-cone structure over all their surfaces, the apices of the cones being directed radially inwards. A similar example occurs in my own collection, and others are described by Prof. Newberry.[7]

As far as I am aware, Mr. Gresley's paper in 1887 is the most distinct and valuable addition to our knowledge of cone-in-cone since the researches of Dr. Sorby, although the author confesses that the structures observed are very complex, and that he himself has no explanation to advance. But in his figures 1 and 2 he shows the serrated surfaces formed where the wall of one cone approaches that of another lying within it. These are well known when visible to the naked eye, but are, as Mr. Gresley showed, worthy of microscopic examination.

When a specimen has been broken, and one cone can be pulled away

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[1] *Quart. Journ. Geol. Soc.* Vol. XLVII. (1891), p. 531 and Pl. XVIII., Fig. 3.

[2] "On the origin of 'cone-in-cone'." *Brit. Assoc Rep.* for 1859, pt. 2, p. 124.

[3] *Geol. Mag.* 1892, p. 139.

[4] *Geol. Mag.* 1886, p. 140.

[5] *Ibid.* 1885, p. 283.

[6] "Notes on 'Cone-in-Cone-Structure," *Geol. Mag.* 1887, p. 17. Also *Quart. Journ. Geol. Soc.* Vol. XLI., Proceedings, p. 110.

[7] *Geol. Mag.* 1885, p. 560.

from a larger one which has surrounded it, the inner surface of the latter is seen to be more or less regularly ridged, the ridges forming little projecting platforms approximately in planes parallel to the base of the hollow cone. This structure is all the more conspicuous in specimens that have become washed and weathered. The microscope shows us that, in such a system of cones fitting one within the other, the cones are separated by an interval of fine muddy material, which occupies the space between the serrations of one cone and the smooth outer surface of that within it (fig. 1). The successive cones may vary in steepness; and horizontal sections across them show that they are not so regularly developed as might be supposed, portions of cones embracing portions of other cones being at least as common as complete cones fitting into others (fig. 2). Their horizontal section reminds one, indeed, of the perlitic structure. Whether this conical subdivision of the mass is due to a tendency to crystallisation, or is merely a type of jointing, may be a matter of opinion ; but I am strongly inclined to connect it with the process of crystallisation of which we have evidence in so many specimens.

Following out the considerations put forward at the beginning of this paper, we may conceive that crystallisation of one constituent of the rock commences at a number of points *on the surface of a bed, or in the interior of a concretion*, the growth radiating outward from these points and tending to form a cone above each, comparable to those figured by Mr. Rutley, and so familiar to students of spherulitic rocks. But there are materials present in the rock which have no such tendency to crystallise; these are forced aside by the crystallising material. though they cannot be entirely got rid of or extruded from the growing cone (fig. 3). As in chiastolite, their presence gives us a clue to the mode of growth and structure of what otherwise would have been a homogeneous mass. We thus learn that the cone is itself built up of a multitude of cone-shaped bodies, reminding one of the primitive bricks in Haüy's theory of crystal-growth. A conical aggregate of crystallites thus succeeds in developing above a point; additional crystallising material creeps towards it laterally and along its surfaces from above or from below; the primary acicular crystal or group of crystals tends to thicken by these additions ; but a quantity of the matrix becomes included, and is pressed and arranged against the surface of the first developed cone. The forces of crystallisation prevail over it, and give it a fairly symmetrical arrangement, and a new sheath to the primary cone is developed, divided from the latter by a film of matrix. The inner surface of this sheath, or outer cone, is ridged, showing serrations in section, since the sheath is built up, as already hinted, of minute conical aggregates comparable to the main structure.[1] The top of the little ridges or platforms running round the interior of the sheath is formed by the union of the tops of these subsidiary cones; on the outside of the sheath their conical surfaces unite to form a new smooth exterior like that of the first developed cone (fig. 1). Sheath after sheath, complete or partial, thus develops round the primary cone, the whole structure also growing upwards, until it is cut short by reaching the other surface of the bed or the surface of the concretion in which it has been able to originate. Although so much of the matrix is thrust aside, an immense quantity of foreign material remains included in the crystalline aggregates; so that the cones are comparable to the rhombohedra of the Fontainebleau sandstone, and their extinctions as continuous crystalline bodies are generally masked. Workers among the products of contact metamorphism will know how a well marked crystal of staurolite or andalusite will be almost unrecognisable in section, owing to the small proportion that the crystallised material bears to the matrix ophitically caught up in it; and this fact must be borne in mind in considering cone-in-cone structure as essentially crystalline. But a specimen in the collections of the Royal College of Science for Ireland gave me the first assurance that this view was a correct one. It was given to Prof. Jukes by Mr. Beckett of Wolverhampton, and comes doubtless from the Coal Measures of that area. Cleavage-surfaces can be detected in it, glancing like those of an ophitic igneous rock when the specimen is turned about in the hand. The material is calcite, with a trace of ferrous carbonate, and the cleavage-surfaces are inclined in various azimuths to the axes of the cones. Crystallisation appears so thorough in this specimen as to at once ally the cones to the radial fibres of the Durham concretions. A section shows corresponding optical continuity of the material, extinction taking place when the axes of the cones are parallel or perpendicular to the diagonals of the nicols. The presence of unextinguished crystalline impurities renders this observation only approximate; but the continuity of extinction in the main mass proves the crystalline character of the cones, while it seems highly probable that the principal axis of the calcite constituent lies parallel to their axis of form.

The building of conical crystalline fibres on a large scale by the aggregation of a multitude of small cones, each with its successively added coats or partial envelopes, is illustrated by the microscopic structure of Prof. Jukes's specimen. Sufficient foreign matter was present to mark

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[1] Cf. W. S. Gresley, *Geol. Mag.* 1887, p. 19.

the several coats. But this may be also quite a common mode of growth in homogeneous materials, the cones only becoming revealed to us, and becoming separable, by the arrangement of the matrix when it is present. The specimens that I have had to hand during the preparation of these notes consist of carbonates of lime and iron: in one of them quartz grains form the bulk of the impurity, standing out like fine sand after treatment of the rock with acid. But cone-in-cone may occur in other materials, wherever radial crystallisation struggles with an uncrystallising matrix. The so-called "Beef," or fibrous calcite, of the Purbeck and other English strata, forms the best link I am acquainted with between cone-in-cone and ordinary fibrous crystallisation.

Very similar structures may be seen on the surfaces of coal, as in some blocks from Wigan lately pointed out to me by the Rev. Maxwell Close. It is possible that these are cases where the impurity is altogether out of proportion to the crystallising material, the latter forming the merest films, since films of calcite still cling in places to the surface of the carbonaceous cones. I am also much indebted to Mr. G. W. Butler, B.A., F.G.S., for several specimens lent me in the course of the present observations.

Fig. 1. Vertical section of cone-in-cone, the crystallising material consisting mostly of ferrous carbonate. Portions of two conical series are seen, the apices directed downwards. The mode in which coats belonging to adjacent cones meet and fit against one another can be seen in the left hand half of the drawing. × 8.

Fig. 2. Horizontal section of cone-in-cone, more argillaceous than the above, showing section of cone, with smaller cones and partially developed conical coats, indicated by the dark and somewhat irregular lines within it. × 12.

Fig. 3. Vertical section of part of the same specimen as that used in fig. 2, showing cones developing in the argillaceous matrix, which has only in part been forced to assume a definite arrangement. × 18.